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ABSTRACT

This paper reports on a hierarchical linear modeling (HLM) investigation of the relationships among baseline science achievement of students in the Science Co-op Local Systemic Change project (grade 3, N=1,134; grade 6, N=1,482), students' attributes (gender, awareness of the nature of science, attitudes toward science, school science and science and technology careers), classroom teachers' characteristics (grade 3, N=98 and grade 6, N=78; students' perceptions of their use of students' ideas, discourse, and collaboration), and classroom factors (students' perceptions roles of the and value of text in classroom science lessons and of parent, home, and community involvement in classroom science programs). Student achievement was measured with multiple forms of the Third International Mathematics and Science Study (TIMSS) released items. Student attributes, teacher characteristics, and classroom factors were assessed by the Students' Perception of Constructivist Classroom (SPOCC-2000) subscales. Separate multi-level analyses of the grade 3 and grade 6 data indicated the extent to which student achievement could be accounted for by student attributes, classroom teacher characteristics, and classroom environment. The relationships of students' gender, awareness, and attitudes with achievement were described. These relationships were investigated as to the extent to which teacher characteristics and classroom factors influenced the weightings of significant student attributes. Awareness of the nature of science significantly influenced science achievement, while attitude toward science, school science, and science and technology careers negatively influence science achievement. Significant gender influence was found for grade 6 students, but not for grade 3 students. Appended are: Grade 3 HLM Results for Multiple-Choice and Student-Generated Response Subscores and Grade 6 HLM Results for Multiple-Choice and Student-Generated Response Subscores. (Contains 22 references.) (Author/JDM)

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Modeling the Relationships of Classroom Characteristics and Student Attributes to Students' Science Achievement

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Abstract

This paper reports a hierarchical linear modeling (HLM) investigation of the relationships among baseline science achievement of students in the Science Co-op Local Systemic Change project (grade 3, N = 1,134; grade 6, N = 1,482), student attributes (gender, awareness of the nature of science, attitudes toward science, school science and science and technology careers), classroom teachers' characteristics (grade 3, N = 98 and grade 6, N = 78; students' perceptions of their use of students' ideas, discourse, and collaboration), and classroom factors (students' perceptions roles of the and value of text in classroom science lessons and of parent, home, and community involvement in classroom science program). Student achievement was measured with multiple forms of the Third International Mathematics and Science Study (TIMSS) released items. Student attributes, teacher characteristics, and classroom factors were assessed by the Students' Perception of Constructivist Classroom (SPOCC-2000) subscales.

Separate multi-level analyses of the grade 3 and grade 6 data indicated the extent to which student achievement could be accounted for by student attributes, classroom teacher characteristics and classroom environment. The relationships of students' gender, awareness, and attitudes with achievement were described; and these relationships were investigated as to the extent to which teacher characteristics and classroom factors influenced the weightings of significant student attributes. Awareness of the nature of science significantly influenced science achievement while attitude toward science, school science, and science and technology careers negatively influence science achievement. Significant gender influence was found for grade 6 students but not grade 3 students.

Modeling the Relationships of Classroom Characteristics and Student Attributes to Students' Science Achievement

Introduction

The Science Cooperatives: Effecting Systemic Change in Rural Missouri and Iowa (Science Co-op) project (2000-2005, NSF Grant ESI 9911857) represents a natural progression of research and development in which a curriculum and instruction innovation, developed, and tested in a single, well-defined condition (Science--Parents, Activities and Literature, 1994-1998, NSF Grant ESI 9353690), is now being scaled up and implemented in a multi-school district context using a special delivery model (Shymansky, et al., 1998a; Shymansky, Yore, Anderson, & Hand 2001). The Science Co-op is a local systemic change (LSC) project that targets 1,200 K-6 teachers and 20,000+ students in 38 small, rural school districts distributed over 40,000 square miles (Figure 1). This LSC project is designed to address the needs of one of the most under-served areas in North America's education system: isolated, small, rural, elementary schools.

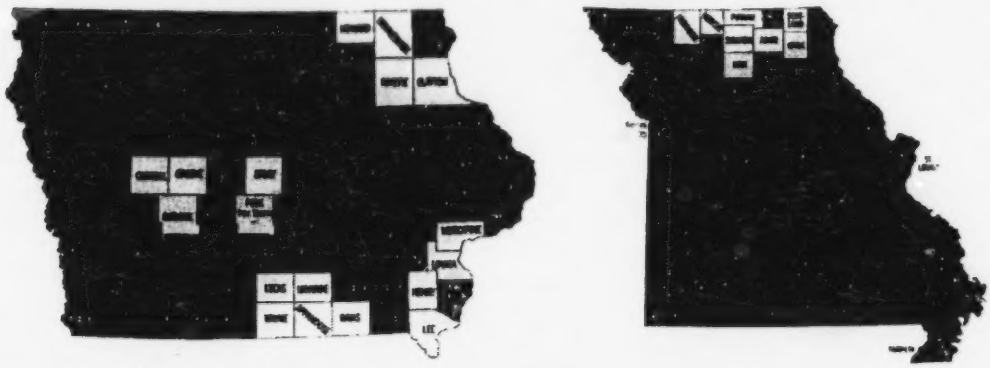

Figure 1. Missouri and Iowa counties involved in the Science Co-op Project (Mabel-Canton, MN School District not shown.)

Science Co-op is based on the farm cooperative movement that allowed small, independent farmers to amass the buying and marketing strength of large farmsteads, to

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share expertise and equipment, and to address common problems. Smaller independent school districts are organized into regional units, cooperatives, so that professional development efforts can be efficiently delivered and local resources can be shared. The National Science Education Standards (NSES) are stressed; and science inquiry, interactive-constructivist teaching approaches, authentic assessment, interdisciplinary connections, and print and electronic resources are promoted through the use of STC, FOSS, and Insights modules. Science Co-op brings together teams of teachers, parents, scientists, and science educators to make science meaningful for children.

Year 0 (1999-2000) of the Science Co-op project was devoted to confirming school district participation, and identifying an elementary teacher in each elementary school building and a secondary science teacher in each school district to serve on the local leadership team. Once the school districts were identified, regional clusters of school districts were established as the science co-ops. These co-ops collaborated on planning future activities and shared resources and staff. Baseline data were collected on school districts, schools, and classrooms using administrator surveys, principal surveys, teacher questionnaires, and classroom observation instruments provided by Horizon Research Inc. (2000a). The Science Co-op project staff also collected additional data about grades 3 and 6 students' science achievement, attitudes toward science, career awareness, perceptions of classroom climate, and constructivist teaching features.

Year 1 (2000-2001) of the Science Co-op project used a combination of a large central summer workshop, regional professional development activities, peer leadership and support activities, weekly two-way interactive video (ITV) sessions, monthly co-op, school district or school building meetings, and internet communications to help the leadership teams construct content-pedagogical knowledge and implement specific science modules stressing reform standards and principles. Science Co-op stresses a cascading leadership model in which lead elementary teachers (science advocates) and supporting secondary science teachers (science partners) become the local leadership team to promote and facilitate science reform in their local school buildings and school districts, to develop customized science kits that utilize elementary teachers' strengths, interdisciplinary connections, and local resources, and to assume increasing responsibility for the other professional development tasks.

Year 2 (2001-2002) of the Science Co-op project started to decentralize responsibility and delivery of the professional development. The divestiture of central control and responsibility for the professional development was incremental, gradually moving the planning, organization, and delivery of the summer workshops from the project staff and external consultants to the regional leadership teams, science advocates, and science partners. Year 2 involved a project-wide leadership meeting, regional organization and implementation meetings focused on a common workshop template, parallel ITV schedules, and a masters degree program designed by the project director, principal investigators, and project staff. Data parallel to the baseline year were collected on school districts, schools, classrooms, and students at the end of the year.

Years 3-5 (2002-2005) of the Science Co-op project are intended to further refine its cooperative infrastructure and to solidify and fine-tune the leadership teams within and across the schools making up the 8 cooperatives. The project's plan and goal is to have in place a leadership team at each district and a common set of professional development activities within the various cooperatives that can sustain an inquiry science culture and support system after the external project funds and staff have been withdrawn. Data parallel to the baseline year and Year 2 will be collected on school districts, schools, classrooms, and students at the end of the project.

An important feature of Science Co-op is the commitment of the individual school district administrators to the LSC project. Unlike early NSF teacher enhancement projects, the LSC project targets systems, not individual teachers. The 8 cooperatives, 38 school districts, 74 elementary school buildings and staffs, and 1,200 elementary classrooms are themselves each a system within the Science Co-op project. It is critical that these systems, subsystems, and components and the relationships among them be described and documented to ascertain if and how the different components and interactions among them have changed and if these changes are closer to the speculated descriptions and relationships. This paper describes the preliminary baseline hierarchical linear models (HLM) of student achievement, student attributes, teacher characteristics, and classroom factors.

Background

Science teaching, science learning, and science teacher education research have enjoyed increased attention and funding in recent years since the publication of the *National Research Council's National Science Education Standards* ([NSES], NRC, 1996a), the *National Board for Professional Teaching Standards* (NBPTS, 1994), and the *Report of the National Commission on Teaching and America's Future* (Darling-Hammond, 1996a). These reform documents reaffirm the importance of teachers, teaching, and hands-on/minds-on learning as primary influences on students' thinking, achievement, and science literacy and describe the complex relationships within the education system. Collectively, the documents provide a vision of what we should teach, how we should teach, what kinds of systems and programs we should teach in, and how we should teach teachers to teach.

An analysis of the current reform documents for language arts, mathematics, science, social studies, and technology revealed a common focus on "all" students, common learning outcomes of literacy and critical thinking, and common instructional intentions regarding constructivism and authentic assessment (Ford, Yore, & Anthony, 1997). Science literacy, like the other contemporary literacies, involves critical thinking, cognitive abilities, and habits-of-mind to construct understanding in the specific disciplines, the big ideas or the unifying concepts of the disciplines, and the communication strategies to share these understandings and to persuade others to take informed action. Some consideration has been given to the inclusion of all students and to authentic assessment. But, little attention has been given to developing a clear definition of constructivism, the pedagogical content knowledge requirements, the associated classroom practices, appropriate learning environments and classroom climates, support roles for school administrators, and systemic curriculum and instructions expectations of the school district and community. The NSES envisioned a change in emphasis involving children's attributes, rigidity of curriculum, relevant learning outcomes, active questioning, alternative assessment, locus of control, and collaboration (NRC 1996). Furthermore, the NSES outline expectations for program opportunities, professional development, and supportive resources and policies. The

National Science Teachers Association (1997) encourages teachers to increase their awareness of these emerging standards for teaching, professional development, assessment, content, program, and the full education system; but little is known about the relationships among these system, subsystem and component variables in elementary school classrooms and science programs.

Science Co-op classrooms stress science programs that involve science inquiry, interactions of students, teacher, and concrete experiences, construction of science understanding, authentic assessment, and print and electronic resources. The interactive-constructivist brand of science teaching promoted is a middle-of-the-road interpretation of constructivism involving the elements of inquiry – engagement, exploration, consolidation, and assessment (Yore, 2001). This project brings together teams of teachers, parents, scientists, and science educators to implement the teaching, assessment, content, program, and system standards of the NSES. Science Co-op is designed to promote and facilitate science reform in local school buildings and school districts and to develop customized science modules that utilize elementary teachers' strengths and local resources. The lead teachers need to understand, value and utilize the NSES, become reflective professional practitioners, and serve as exemplary models of inquiry teaching. The Science Co-op project assumed at its outset that some of these components were present in the existing science programs of some participating school districts, while they were absent in other participating schools and classrooms.

Since Science Co-op professional development activities attempt to model an interactive-constructivist teaching approach based on a modified learning cycle of engage, explore, consolidate, and assess, it is critical to assess the perceptions and understandings that the participating teachers and students bring to the project at its outset. Some studies have demonstrated that teachers do not value many of the constructivist approaches and the reform principles promoted by the NSES and, in fact, hold preconceptions and beliefs that constitute significant barriers to change (Czerniak, Lumpe, & Haney, 1999; Haney, Czerniak, & Lumpe, 1996). Teachers need to understand and value these proposed ideas and, upon reflection, identify the specific changes that are needed in their science program, and be willing to initiate these changes into their classroom practices. Many effective teachers of science are already utilizing much of the

NSES, and concerned reflective teachers are actively trying to incorporate these ideas into their teaching of science. Other concerned teachers falsely believe they are utilizing these ideas in their teaching and see no reason to modify their classroom practices, while some teachers disagree with the proposed changes and are unlikely to incorporate any conflicting ideas into their teaching. It is these last two groups of teachers that confound many research studies about the effectiveness of professional development and teacher enhancement.

Effective elementary science instruction is the result of a complex web of policies, supports, resources, beliefs, talents, and actions. LSC projects need to identify the strength of these relationships and of the various groups of teachers and plan professional development activities that utilize effective teachers of science as models and address the current status of the other groups of teachers. Previous teacher enhancement research studies may have allowed the lack of changes for the effective teachers group and the resistant teachers group to mask the changes of the reflective and the misinformed concerned teachers groups (Shymansky, Yore, & Anderson, 1999). It is likely that the relationships among achievement, attitudes, beliefs, perceptions, and demonstrated use for these groups of teachers and their students will become more explicit and defined as effective professional development occurs during a LSC project.

Professional development of teachers has not been an overwhelming success in the last 40 years (Supovitz & Turner, 2000). Traditional models of professional development, short-term workshops, and university courses do not appear to be robust enough to achieve the current science reform. Loucks-Horsley and Matsumoto (1999) proposed a model for effective professional development involving a layered context, fundamental principles regarding teacher learning, and expertise and then identified 15 activities that appear to be effective with teachers of mathematics and science. The model considers teacher enhancement as a normal professional expectation within the culture and context of national, state and local education systems, schools, communities, and families. Intensive and sustained activities to immerse teachers into inquiry that encourage questioning and promote experimenting with authentic teaching tasks will enhance teachers' pedagogical-content knowledge and strategies, and their awareness of the reform standards and planned school change (Loucks-Horsley & Matsumoto, 1999;

Supovitz & Turner, 2000). Furthermore, effective professional development needs to develop the leaders for future innovations and changes. Science instruction requires resident advocacy to ensure proper consideration and effort.

Darling-Hammond (1996b) suggested that reform efforts that focus on teachers learning and on empowering teachers to interpret, internalize, and implement planned changes in their classrooms and schools are the most promising approaches to improving schools and schooling. Standards, policies, and regulations cannot achieve the impact outlined in the NSES. She believed that only collaborations among teachers, administrators, and parents that consider the multiple perspectives of teachers, schools, communities, families, and children and that develop teachers' pedagogical-content knowledge, teaching strategies, and leadership can achieve these innovations.

Supovitz and Turner (2000) found positive HLM relationships for quality professional development and teachers' self-reported inquiry-based classroom practices and classroom investigative culture. They suggested that negative effects on inquiry-based practices and investigative culture occur within the early phases of the professional development and that positive effects did not start to appear until after 40-79 hours of professional development had been completed. Reform-based professional development, like conceptual change instruction, can be unsettling for established teachers not wanting to give up or change instructional practices and beliefs that they are not certain require revision. In fact, it may be that effective teachers become less effective as they change their practices and beliefs before becoming effective with the new approach. Results of this study appear to suggest that improvement in classroom practices encountered a 'ceiling effect' at the 80-159 hours of professional development, while the investigative culture appeared to improve over the full range of the professional development exposure. The hierarchical linear modeling revealed the influences of the teacher's gender, experience, content background and attitudes, the school's wealth, and the principal's support; but the type of community had little influence on the effects of professional development.

Shymansky, Yore, Anderson, and Hand (2001) explored whether elementary science teachers in the Science Co-op project resonate with the fundamental principles of the NSES, whether they see themselves as implementing these principles in their science

teaching, and whether they actually demonstrate these principles in their classroom science teaching. Teachers participating in the project completed a two-part survey designed to assess (a) the degree of agreement with belief statements based on the project's goals and the NSES and (b) their perceived usage of these principles in their science teaching. Trained observers using a common 5-dimension holistic rubric for assessing science teaching observed a non-random sample of teachers completing the survey (Horizon Research Inc., 2000b). The survey data were subjected to factor analyses, correlation analyses, and regression analyses. The teacher questionnaire subscales assessed beliefs and perceptions about student-centered features, purposeful inquiry, relevance and meaningful learning, and conceptual change. The classroom observations provided ratings of design, implementation of an interactive-constructivist approach, science content, classroom culture, and global performance. The descriptive statistics indicated that these teachers did not fully embrace or implement the instructional principles of the NSES and the project. The correlations revealed non-significant positive and negative associations among beliefs, perceptions, and classroom performance. The regression analyses revealed that significant relationships between science teaching, beliefs, and perceived implementation did not exist for these teachers at the beginning of the Science Co-op LSC project.

The lack of significant relationships among beliefs, perceptions, and actions on which the surveys and observations focused was not surprising, considering that these were baseline data collected prior to any professional development. Most teachers were only vaguely familiar with the NSES and only slightly more familiar with their state's reform initiatives. Many of the teachers' beliefs about the science reform and interactive-constructivist principles were based more on intuitive and hearsay conceptions of science reform principles rather than on a thoughtful, informed analysis of those principles. This view is supported by a separate survey of the 85 building principals, which revealed only minimal awareness of the NSES and science reform principles and no formal district efforts to promote either. In addition, less than 5% of the teachers in the participating districts indicated that they had examined a copy of the NSES or attended any kind of meeting where the NSES or reform ideas had been discussed. These results motivated the

current study of the relationships among student achievement, student affective attributes, teacher characteristics, and classroom environmental factors.

Design

This study involved a hierarchical linear modeling (HLM) investigation of the complex relationships between and among science achievement, student characteristics, and classroom factors. Unlike, the earlier study involving correlation and regression analyses of teachers' beliefs, perceived implementation and classroom performance, the current study involved multiple-levels of information—students and classrooms. HLM was judged to be the appropriate statistical analysis since the variables were multiple-level and defined by nominal or ordinal scales and the central goal of the study was to model the nested relationships within the variables with no intention of exploring the existence of latent variables inherent in structural equation modeling (Bryk & Raudenbush, 1992; Hayduk, 1987). The Science Co-op project and other LSC projects collect information on various levels of the local system – community, school district, school building, classroom teachers, class size, and students. This study involved the modeling of the baseline science achievement of students (grades 3; N = 1,134 and grade 6; N = 1,482) with student attributes, classroom teacher characteristics, and classroom environmental factors. School district, community, and school building were not included in this study because of unresolved data linkage difficulties.

Instruments and Data Collection

Student achievement in 38 school districts and 74 elementary schools was measured on the science achievement tests constructed from the Third International Mathematics and Science Study (TIMSS) released multiple-choice and open-ended items. The grade 3 tests had 4 forms with 15 common multiple-choice and 3 common student-generated response items across all forms, two sets of 10 common multiple-choice items across 2 (31A and 31B; 32C and 32D) of the 4 forms, and 4 unique student-generated response item on each form. The grade 6 tests had 6 forms with 20 common multiple-choice items across all forms, two set of 17 common multiple-choice items across 3 (61A, 61b and 61C; 62D, 62E and 62F) of the 6 forms, and 6 unique student-generated response items on each form. The various forms for each grade level were sorted into

mixed classroom sets and randomly distributed to students in the grade 3 or grade 6 classes. Students attending school on the test day completed the test form received and the common student information cover page. These data were collected at the beginning of the local systemic change project (May 2000). The TIMSS tests provided achievement scores on the multiple-choice items, student-constructed response items, and the total test for most biological, earth-space, and physical science topics in grade 3 and grade 6 science programs. The students' science achievement scores from 4 forms of the grade 3 tests and from 6 forms of the grade 6 tests were separately analyzed to evaluate equality of performance by groups of students in a class completing different forms with multiple-choice or student-generated response items common to all forms. The results indicated statistical equivalence of performance on the common items across these random groups of students. The test scores for each form were converted into standard scores for the multiple-choice items, the open-ended response items, and the total TIMSS test. The average percent correct on the total TIMSS tests across the Science Co-op project was 49.5% for Grade 3 students (males = 50.3%, females = 48.7%) and 52.2% for Grade 6 students (males = 52.8%, females = 51.8%).

The students' affective attributes toward and perceptions of science, school science teaching and science learning were assessed with the Student's Perceptions of Constructivist Classrooms (SPOCC-2000) survey (Yore, Shymansky, & Anderson, 2001). The 60-item SPOCC-A survey was administered to grade 3 students and the 65-item SPOCC-B survey was administered to grade 6 students at the start of the Science Co-op project. The SPOCC inventories assessed 5 major dimensions corresponding to the factor structure of the instrument design based on the desired interactive-constructivist approach and the national science reform:

- Subscale 1--Awareness of the Nature of Science;
- Subscale 2--Attitudes toward Science, School Science, and Science and Technology Careers;
- Subscale 3--Using Children's Ideas, Discourse, and Collaboration;
- Subscale 4-- Roles and Value of Text; and
- Subscale 5--Parent, Home, and Community Involvement.

Subscales 1 and 2 were considered to be student attributes, while subscales 3, 4 and 5 were considered to be classroom teacher characteristics or classroom environmental factors.

Student attributes available were grade level, gender, awareness (awareness of the nature of science), and attitudes (attitudes toward science, school science, and science and technology careers). Teacher characteristics (98 grade 3 teachers, 78 grade 6 teachers) included students' perceptions of the teacher using students' ideas, discourse and colaboration. Classroom environmental factors included students' perception of the role and value of text in classroom science lessons and of parent, home, and community involvement in the classroom science program.

Data Interpretation and Analysis

HLM analyses were conducted separately with grade 3 or grade 6 students as the level 1 unit and classrooms as the level 2 unit. The models to be fitted can be generally described as:

Level 1- Students

Science Achievement$_{ij}$ = β_{0j} + β_{1j} (gender) + β_{2j} (Awareness of the nature science) + β_{3j} (attitudes toward science, school science, and science and technology careers) + r_{ij}

Level 2 - Classrooms

β_{0j} = γ_{00} + γ_{01} (Teacher characteristics—Uses students' ideas, discourse, and collaboration) + γ_{02} (Classroom environment—Role and value of text) + γ_{03} (Classroom environment—Parent, home, and community involvement) +u_{0j}

β_{1j} (gender) = γ_{10} + γ_{11} (Teacher characteristics—Uses students' ideas, discourse, and collaboration) + γ_{12} (Classroom environment—Role and value of text) + γ_{13} (Classroom environment – Parent, home, and community involvement) +u_{1j}

β_{2j} (awareness) = γ_{20} + γ_{21} (Teacher characteristics—Uses students' ideas, discourse, and collaboration) + γ_{22} (Classroom environment—Role and value of text) + γ_{23} (Classroom environment – Parent, home, and community involvement) +u_{2j}

β_{3j} (attitudes) = γ_{30} + γ_{31} (Teacher characteristics—Uses students' ideas, discourse, and collaboration) + γ_{32} (Classroom environment—Role and value of text) + γ_{33} (Classroom environment – Parent, home, and community involvement) +u_{3j}

Where u_{0j} , u_{1j} , u_{2j} and u_{3j} are error terms associated with class-level differences; β_{0j} , β_{0j} , β_{0j} and β_{0j} are level 1 coefficients of student attributes, and γ_{00}, γ_{01}, γ_{02}, γ_{03} … γ_{32}, and γ_{33} are level 2 coefficients for the predictor classroom teacher characteristics and classroom environmental factors and r_{ij} denotes student level error.

The analyses indicated the extent to which student achievement differences could be accounted for by gender and student affective attributes. Furthermore, the strength of these relationships was described in terms of the extent to which classroom teacher characteristics and classroom environment factors influenced the weighting of student's gender and affective attributes relationships to science achievement.

Results

A progressive series of more focused HLM analyses of the grade 3 and the grade 6 data separately were used to eliminate non-significant student attributes in the general model and to produce the best-fit linear model for each grade level. These analyses started with the most complex, general Level 1 equation dealing with individual science achievement scores, gender, awareness of the nature of science, and attitudes toward science, school science and science, and technology careers and were followed by explorations of the associated set of Level 2 equations dealing with the coefficients for the Level 1 equation relationships--teacher characteristics (Perceived use of students' ideas, discourse, and collaboration) and classroom characteristics (Perceived role and value of text in classroom science lessons; Perceived parent, home, and community involvement in the classroom science program).

The grade 3 results yielded the follow linear model for students' science achievement measure by the total TIMSS score:

Level 1 Model of Student Characteristics

Total TIMSS = β_{0j} + β_{2j} Awareness of the Nature of Science score + β_{3j} Attitudes Toward Science, School Science, and Science and Technology Careers score + r_{ij}

Level 2 Model of Classroom Teacher Characteristics and Environmental Factors

β_{0j} = 19.97 + Significant u_{0j}

β_{2j} = 3.85 + 2.94 Perceived Teacher's Use of Students' Ideas, Discourse, and Collaboration

β_{3j} = – 0.83 – 1.37 Perceived Role and Value of Text in Classroom Science Lessons

Surprisingly, the grade 3 analyses revealed that there were no significant gender influence nor between class differences for classroom teacher characteristics and classroom environmental factors influences on student attributes. The grade 3 results indicated that students' perception of teacher's use of their ideas, discourse, and collaboration was a significant positive influence on the weighting of the awareness of the nature of science that in turn was a significant positive influence on science achievement measured by the total TIMSS score, and that students' perception of the role and value of text in classroom science lessons was a significant negative influence on the weighting of attitudes toward science, school science, and science and technology careers that in turn was a significant negative influence on science achievement. Perception of parent, home, and community involvement in the classroom science program was not a significant classroom influence on student attributes.

The grade 6 results yielded the follow linear model for students' science achievement measure by the total TIMSS score:

Level 1 Model of Student Characteristics

Total TIMSS = β_{0j} + β_{1j} Gender + β_{2j} Awareness of the Nature of Science score + r_{ij}

Level 2 Model of Classroom Factors

β_{0j} = 23.61 –1.96 Perceived Role and Value of Text in Classroom Science Lessons +Significant u_{0j}

β_{1j} = –1.30

β_{2j} = 4.60

The grade 6 analyses revealed that there were no significant attitudes toward science, school science, and science and technology careers influence nor between class differences for classroom teacher characteristics and classroom environmental factors influences on student attributes. Furthermore, these analyses revealed that students' gender and awareness of the nature of science significantly influenced science achievement measured by the total TIMSS score, and that students' perception of the role and value of text was a significant negative influence on the weighting of the gender's influence on science achievement. Male students achieved better total TIMSS scores than did female students, and the higher perceptions of role and value of text in classroom science lessons exacerbated the strength of this influence. Students' attitudes toward science, school science, and science and technology careers did not exert significant influence on science achievement measure by the total TIMSS test. Furthermore, students' perceptions of the classroom teacher's use of students' ideas, discourse and collaboration and students' perceptions of parent, home, and community involvement in the classroom science program were not significant Level-2 classroom influences.

Similar HLM analyses were conducted on the subscores of the TIMSS test—the multiple-choice items and the student-generated response items. These analyses confirmed the general Level 1 models of student characteristics for grade 3 and grade 6, but the Level 2 models of classroom teacher characteristics and environmental factors influence on the mean scores and the coefficients for the student attributes were somewhat different. Summary results of these analyses are provided in Appendices A and B. The grade 3 HLM Level 2 results for multiple-choice subscores indicated that students' perception of parent, home, and community involvement in the classroom science program influence the coefficient of students' awareness of the nature of science and that students' perception of the role and value of text in classroom science lessons did not influence the coefficient of students' attitudes toward science, school science, and science and technology careers. The HLM results of grade 3 student-generated response subscores indicated that Level 1 model of students' characteristics was the same as for the total TIMSS scores, but that students' perceptions of teachers use of students' ideas, discourse, and collaboration did not significantly influence the coefficient of the awareness of the nature of science and that students' perceptions of the role and value of

text in classroom science lessons did not significantly influence the coefficient of the students' attitudes toward science, school science, and science and technology careers.

The Level 1 and Level 2 HLM results of the grade 6 multiple-choice subscores were the same as the results for the total TIMSS scores. The grade 6 Level 1 HLM results for the student-generated response subscores indicated that gender did not significantly influence performance on this type of achievement and the Level 2 results indicated that students' perception of the role and value of text in classroom science lessons did not influence the mean achievement on student-generated response items.

Discussion

Little is known about the relationships among communities, school systems, elementary building subsystems, and components in elementary classrooms and science instruction (teachers, students, resources, space, time, etc.) and their ultimate influence on students' science achievement. Science Co-op promotes science programs that involve science inquiry, interactions of students, teacher, and concrete experiences, construction of science understanding, authentic assessment, and print and electronic resources. The interactive-constructivist teaching involves the elements of inquiry – engagement, exploration, consolidation, and assessment (Yore, 2001). Elementary science instruction is the result of a complex web of policies, programs, supports, resources, beliefs, talents, and actions. NSES (NRC, 1996) program and system standards stress:

- Program elements must be articulated with the other NSES standards and coordinated across the K-12 system and with the mathematics program.
- Program frameworks should guide decisions about curriculum, instruction, and resources and be aligned with assessment strategies, goals, and student expectations.
- Program frameworks should be developmentally appropriate, interesting, and relevant to the target students.
- Programs must give student access to appropriate and sufficient resources, teachers, time, safe space, and community and access to opportunity.

- Programs should encourage schools to work as communities that encourage, support, and sustain teachers' implementation efforts.
- Policies that influence the practice of science education must be congruent with NSES standards adapted to local circumstances, coordinated within and across authorities, sustained over sufficient time, supported with resources, be equitable and be reviewed for unintended effects.
- Responsible individuals must promote and ensure the attainment of the reform vision—Science Literacy for All Americans.

LSC projects need to identify the strength of these relationships among these systems, subsystems and components and the various groups of teachers, administrators, community members within the system, as well, LSC projects need to plan professional development activities that encourage effective teachers of science and address the current status of the less-effective groups of teachers. But above all, these changes in the community, school district, schools, teachers, and science program must result in science literacy for all students and improved science understandings, awareness of the nature of science and attitudes toward science, school science, and science and technology careers.

The specific results of this study suggest that some kind of student attributes and classroom environmental factors appear in grade 6 that produce a significant gender influence on science achievement. These individual attributes and classroom characteristics do not appear to play a significant role in grade 3. In future studies, gender needs to be described by more than sex of the student (male=1, female=2); genders is a multi-variant sociocultural characteristic that might involve community expectations, classroom organization, instructional approaches, curricular topics, and assessment strategies. The grade 6 student-generated response subscores analysis indicated that the gender difference may be an artifact of the test item type. This suggests that alternative techniques need to be explored as part of any equitable assessment (see recent literature review and study by Weaver & Raptis, 2001).

The relatively simple models of science achievement, student attributes, classroom teacher characteristics, and classroom environmental factors found for these grade 3 and grade 6 baseline data did not approximate the complex models expected, but

they were not surprising for school systems entering into a 5-year project to implement local systemic change to their science programs. Furthermore, it is interesting to note the lack of variation in level 2 influences (u_{1j} , u_{2j} & u_{3j}) across grade 3 and grade 6 classes in the 38 school districts. This indicates the similarity across school districts and classes in this project and the potential for change in these 38 school systems over 5 years. If the Science Co-op LSC project is successful, the HLM results for Year 5 data should illustrate a much more complex set of models and relationships among student achievement, student attributes, classroom factors, teacher characteristics, and school district and community factors. The Science Co-op project was based on a set of design principles from the NSES (1996) in which:

- Communities explicitly value and promote science literacy for all students. School districts establish school improvement plans in which inquiry-based science, interactive-constructivist teaching and learning, and multiple forms of authentic assessment are assigned priority, reform-based curriculum policy are established, and explicit instructional time expectations are promoted.
- Elementary school principals implement district plans, programs and policies, support classroom teachers' attempts to implement reform-based science curriculum, teaching and assessment, and provide the required resources for inquiry science instruction.
- Elementary teachers develop the beliefs, values, pedagogical content knowledge, and classroom practices necessary to teach science as described in the NSES.
- Elementary students perceive and respond to the science curriculum, teaching, and assessment changes implemented by their teachers and achieve acceptable standards of science literacy—cognitive abilities and habits of mind, understanding of the big ideas in science, communication skills to inform and persuade other people about these science ideas, and the impact on real-life situations dealing with science, technology, society, and the environment.

If the school system changes do not influence the classroom subsystems and students' science literacy, the Science Co-op LSC will not have been successful!

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Appendix A. Grade 3 HLM Results for Multiple-Choice and Student-Generated Response Subscores

Multiple-Choice HLM Results

Level 1 Model of Student Characteristics

Multiple-Choice TIMSS = β_{0j} + β_{2j} Awareness of the Nature of Science score + β_{3j} Attitudes Toward Science, School Science and Science and Technology Careers score + r_{ij}

Level 2 Model of Classroom Factors

β_{0j} = 14.30 + Significant u_{0j}

β_{2j} = 2.94 + 3.65 Perceived Teacher's Use of Students' Ideas –2.76 Perceived Parent, Home and Community Involvement

β_{3j} = – 0.50

Student-Generated Response HLM Results

Level 1 Model of Student Characteristics

Student-Generated Responses TIMSS = β_{0j} + β_{2j} Awareness of the Nature of Science score + β_{3j} Attitudes Toward Science, School Science and Science and Technology Careers score + r_{ij}

Level 2 Model of Classroom Factors

β_{0j} = 5.60 + Significant u_{0j}

β_{2j} = 0.90

β_{3j} = – 0.27

Appendix B. Grade 6 HLM Results for Multiple-Choice and Student-Generated Response Subscores

Multiple-Choice HLM Results

Level 1 Model of Student Characteristics

Multiple-Choice TIMSS = β_{0j} + β_{1j} Gender + β_{2j} Awareness of the Nature of Science score + r_{ij}

Level 2 Model of Classroom Factors

β_{0j} = 20.62 –1.89 Perceived Role and Value of Text +Significant u_{0j}

β_{1j} = –1.15

β_{2j} = 3.65

Student-Generated Response HLM Results

Level 1 Model of Student Characteristics

Student-Generated Response TIMSS = β_{0j} + β_{2j} Awareness of the Nature of Science score + r_{ij}

Level 2 Model of Classroom Factors

β_{0j} = 4.77 +Significant u_{0j}

β_{2j} = 0.96

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